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SOME STUDIES IN BLOSSOM COLOR INHERITANCE IN TOBACCO, WITH SPECIAL REFERENCE TO N. SYLVESTRIS AND N. TABACUM

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THE blossoms of varieties of *Nicotiana tabacum* exhibit three distinct colors, white, carmine and pink.[1]

In the writer's crossing experiments, two white-flowered nicotianas were used, *N. sylvestris,* a species with long, slender, pure white blossoms, and a variety of *N. tabacum* from Honduras (S. P. I. No. 30887), with rather small, pure white blossoms of the *tabacum* type. The pink-flowered variety generally used was the Connecticut Broadleaf variety, although the varieties 70-leaf Cuban, a mammoth type of Cuban which appeared as a mutation in Connecticut in 1912, and Maryland Mammoth also were used. The carmine-blossomed tobacco[2] is a variety of *tabacum* sold by various seedsmen for ornamental purposes under the name giant red-flowering tobacco. This variety breeds true to blossom color and crosses readily with all the commercial varieties of *tabacum.*

CROSSES OF PINK-FLOWERED VARIETIES WITH CARMINE-FLOWERED VARIETIES

In the crosses Pink ♀ × Carmine ♂ and their reciprocals, Carmine, without exception, has been perfectly dominant, so that all the blossoms of first generation plants bear carmine flowers.

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[1] The colors carmine and pink have been compared with Ridgway's Color Standards and Color Nomenclature, 1912 edition. The carmine is practically identical with Ridgway's carmine, shown on Plate 1. The pink matches almost exactly his Hellebore Red, shown on Plate 38.

[2] There seems to be little definite information at hand concerning the origin of the carmine-flowered varieties of *N. tabacum.* O. Comes, in his monograph "Delle Razze Dei Tabacchi," *Atti. Del R'Inst. d'Incoraggiamento di Napoli,* Serie 6, 1905, pp. 77–306, speaks of the Nepal tobacco, a variety of *N. tabacum,* as having intensely red blossoms. The Rano variety is also said to have distinctly red blossoms.

TABLE I

FIRST GENERATION PLANTS OF CROSS CARMINE × PINK

Year	Row	Cross	No. of Plants	Remarks
1915	26A	Carmine ♀ × Pink (Md. Mammoth) ♂......	21	All carmine
1916	21C	Pink (70 leaf Cuban) ♀ × Carmine ♂......	27	" "
1916	26A	Carmine ♀ × Pink (70 leaf Cuban) ♂......	22	" "
1916	35A	Pink (Conn. Broadleaf) ♀ × Carmine ♂....	26	" "
1917	114A	Pink (Conn. Broadleaf) ♀ × Carmine ♂....	50	" "
Total...			146	All carmine

TABLE II

SECOND GENERATION PLANTS OF CROSS CARMINE × PINK

Year	Row	Cross	No. of Plants	Red	Pink
1915	27B	Carmine ♀ × Pink (Md. Mammoth) ♂...	15	13	2
1916	19B	Pink (Conn. Broadleaf) ♀ × Carmine ♂...	39	30	9
1917	90B	Pink (Conn. Broadleaf) ♀ × Carmine ♂...	10	6	4
1917	91B	Pink (Conn. Broadleaf) ♀ × Carmine ♂...	42	29	13
1917	107C	Pink (Conn. Broadleaf) ♀ × Carmine ♂...	23	19	4
1917		Pink (Conn. Broadleaf) ♀ × Carmine ♂...	153	114	39
Total..			282	211	71

From the data shown in Tables I and II, it is evident that the characters pink and carmine behave as typical unit characters, with carmine completely dominant. Segregation takes place in the 2d generation into carmine and pink blossomed plants very close to the theoretical ratio of 3 to 1.

A heterozygous plant of the first generation of the cross Pink (Conn. Broadleaf) ♀ × Carmine ♂ was then crossed with homozygous carmine. Of 115 plants obtained in this cross, all were carmine in color, which is in accord with the expected result.

Heterozygous plants of the first generation were now crossed with recessive pink with the following results.

From these results it is evident that the theoretical ratio 1:1 which obtains in such a cross is very closely approached.

TABLE III

Crosses Between Heterozygous Plants of the First Generation of the Cross (Pink ♀ × Carmine ♂) and Pink

Year.	Row.	Cross.	No. of Plants	Red	Pink
1915	18A	A first generation plant of the cross [Pink (Conn. Broadleaf) ♀ × Carmine ♂] ♀ × Pink (White Burley Mammoth) ♂	19	7	12
1915	22	A first generation plant of the cross [Pink (Conn. Broadleaf) ♀ × Carmine ♂] ♀ × Pink (White Burley Mammoth) ♂	41	17	24
1915	26B	A first generation plant of the cross [Pink (Conn. Broadleaf) ♀ × Carmine ♂] ♀ × Pink (Md. Mammoth) ♂..............	19	11	8
1915	28B	A first generation plant of the cross [Pink (Conn. Broadleaf) ♀ × Carmine ♂] ♀ × Pink (White Burley Mammoth) ♂	16	7	9
1917		A first generation plant of the cross [Pink (Conn. Broadleaf) ♀ × Carmine ♂] ♀ × Pink (White Burley Mammoth) ♂	197	91	106
1917		A first generation plant of the cross [Pink (Conn. Broadleaf) ♀ × Carmine ♂] ♀ × Pink (Conn. Broadleaf) ♂.............	249	130	119
Total..			541	263	278

In further studies of the cross Carmine × Pink, the progenies of many extracted, recessive pink-flowered plants of the second generation have been grown, and all have produced pink-flowered lines. Of the carmine-flowered plants of the second generation, some (the heterozygous) have again broken up into Carmine and Pink, while others (homozygous) have given pure Carmine lines.

Crosses Involving Carmine of Pink with White

In crosses involving Carmine or Pink with White, white has behaved as a recessive, whether the cross has been made with the white-flowered species *N. sylvestris,* or with the white-flowered variety of *N. tabacum* S. P. I. No. 30887 from Honduras. Carmine, however, is not perfectly dominant in these crosses for plants of the first generation are somewhat lighter red than the carmine itself. In the cross Pink × White (*N. sylvestris*) the blossoms of the first generation are somewhat paler than the usual pink of the tabacum varieties. In crosses between pink-flowered varieties of *N. tabacum* and White (S. P. I. No. 30887 from Honduras) white has behaved as a recessive. The intensity of the dominant pink depends upon the pink variety used. In some crosses, the blossoms of the first generation plants are similar in color to the pink of the pink parent. In other crosses, the pink of the first generation plants may be noticeably deeper than that of the pink-flowered parent.

A number of heterozygous plants of the first generation of the cross Pink (Conn. Broadleaf) ♀ × Carmine ♂ have been used as mother plants and crossed with the recessive white *N. sylvestris*, with the following results:

42 plants, of which 25 were carmine blossomed and 17 pink blossomed.
41 plants, of which 23 were carmine blossomed and 18 pink blossomed.

Here we have a total of 83 plants, of which 48 possessed Carmine blossoms and 35 possessed Pink blossoms, showing an approximation to the 1:1 ratio. In crosses involving the species *N. sylvestris*, some difficulties are involved, since the first generation plants are usually sterile or nearly so. However, this sterility has been overcome in the cross in which a first generation plant of the cross (Pink (Conn. Broadleaf) ♀ × Carmine ♂) was pollinated with the pollen of *N. sylvestris*. In the second generation of this cross, whites, pinks and carmines appeared. A number of carmine plants were selected and their progenies studied. One known as no. 12, proved to be homozygous for carmine and has bred true to this color for several generations. A sister plant no. 9 with carmine blossoms proved to be heterozygous. In a progeny of 32 plants obtained from this plant, 26 were carmine and 6 were pink blossomed, approximating the theoretical ratio 3:1.

In the cross Carmine × White, using the white-flowered variety of *N. tabacum* S. P. I. No. 30887 from Honduras, the plants produce an abundance of fertile seed. As has been stated, carmine is dominant over white, but it is not a perfect dominance as in the cross Carmine × Pink, for the blossoms of the first generation plants are somewhat paler than pure carmine. In the second generation there is a segregation into whites, and various degrees of pinks and reds, ranging from light pink to pure carmine. Of 278 second generation plants of this cross, grown in 1917, the blossom colors were grouped as follows:

White	65
Dark pink	26
Light pink	38
Lighter than carmine	95
Carmine	54
Total	278

It is evident that the recessive whites which were easily determined approximated very closely the theoretical 25 per cent. Owing, however, to the uncertainty of analyzing correctly the varied pinks and reds, the carmines which probably represent the homozygous dominants are somewhat below the theoretical 25 per cent. It is quite probable that this class is somewhat smaller than it should be, owing to the difficulty of distinguishing with certainty all the homozygous carmines from the heterozygous somewhat paler carmines.

A number of extracted, recessive whites of the second generation of this cross have been grown and all have produced white-blossomed progenies. These white-blossomed plants have proved somewhat puzzling, however, for some seemed to reveal a hint of color, like an almost imperceptible sheen, that could be detected only in certain lights. So fugacious was this suggestion of color, that I felt inclined to ascribe it to the imagination, until certain crosses were made with pink-flowered varieties as follows:

From the cross Pink (Maryland Mammoth) ♀ × White (extracted) ♂, 54 first generation plants were obtained, of which 17 were carmine, 18 were pink as in the Mammoth, and 19 somewhat lighter than carmine.

In the reciprocal of this cross, *i. e.*, White (extracted) ♀ × Pink (Md. Mammoth) ♂, 43 plants were obtained, of which 20 were carmine, and 23 were pink blossomed as in the Mammoth.

This same extracted white-flowered plant was also crossed with Pink (Conn. Broadleaf) as follows:

From the cross Pink (Conn. Broadleaf) ♀ × White (extracted) ♂, 51 first generation plants were obtained, of which 12 were carmine or approaching it, and 39 were pink approximating the pink of the Broadleaf parent. It is apparent that the extracted white used in these crosses has somehow retained the factor of Carmine which reappeared in the cross with Pink.

From the results reported in this paper, the Mendelian behavior of the cross Carmine × Pink is particularly striking, and for those who wish to demonstrate before students interested in questions of heredity simple Mendelian behavior in a monohybrid, this particular tobacco cross is especially suitable. Not only is the technique of crossing easy, but a single fertile capsule from a cross will produce several thousand seed. Furthermore, tobacco plants may be readily grown to the flowering stage, in five or six inch pots under greenhouse conditions.

Summary

Among the varieties of tabacum, carmine and pink in crosses behave as unit characters, carmine being dominant. In the second generation perfect Mendelian segregation follows, approximating very closely the theoretical ratio of three carmines to one pink. The extracted recessive pinks and the homozygous carmines breed true. The heterozygous carmines again break up into carmine and pink. If a heterozygous plant of the first generation is crossed with a pure carmine, the progeny will all produce carmine blossoms. If it is crossed with a pink, carmines and pinks will appear in the progeny, approximating the ratio 1 to 1.

In crosses involving carmine or pink with white, white behaves as a recessive, appearing in the second generation.